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(54) **VIDEO NOISE REDUCER**

VIDEO-RAUSCHVERMINDERUNG

REDUCTEUR DE BRUIT VIDEO

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Description

[0001]   This invention relates to video noise reducers and methods of noise reduction.

[0002]   A well known method for the reduction of noise in a video signal employs a recursive filter. The method operates by averaging similar areas in successive images and relies on the fact that the true image information in a video signal is highly correlated. Noise, however, is generally random and is attenuated in the averaging process. A recursion constant **k** determines the relative weightings of the current and preceding frames in the averaging process and thus the number of frames over which effective averaging takes place. Significant attenuation of noise can be achieved with averaging over a relatively small number of frames.

[0003]   It is well understood that the picture correlation upon which recursive noise reduction relies, breaks down where there is movement (or shot changes) in the input images. It is important to disable the recursion when movement is detected; failure to do this will result in image smear. Motion adaptive noise reduction has the annoying artifact, that picture regions at the edges of moving objects are substantially noisier than the surrounding picture, and noise increases after a shot change. An edge of a moving object is associated with disabling of recursive noise reduction so that each edge of the moving object will be followed by a region of signal which is not noise reduced. The problem is exacerbated by the need - usually - for the motion detector signal to be filtered spatially; this results in an even larger area which lacks noise reduction. It is also the case that the more effective is the noise reduction process over the image as a whole, the more noticeable are the noisy regions around moving objects.

[0004]   It is an object of this invention to provide an improved video noise reducer and method of noise reduction which removes or reduces the above problem.

[0005]   Accordingly, the present invention consists, in one aspect, in a method of noise reduction in a video signal, in which pixel information is recursively filtered to produce a noise reduced output, with recursion being disabled at a disjuncture so that pixel information after the disjuncture is not recursively combined with pixel information prior to the disjuncture, wherein, after the disjuncture, recursively filtered pixel information prior to a disjuncture continues to provide the noise reduced output, until pixel information after the disjuncture has been recursively filtered to an appropriate degree of noise reduction.

[0006]   Advantageously, on detection of a disjuncture in the form of a shot change, from a first shot to a second shot, outputting of fields from the second is delayed until sufficient fields have been recursively filtered for the noise level on the second shot to have been reduced to approximately that of the first.

[0007]   Suitably, on detection of a disjuncture in the form of motion, outputting of pixels arising after the disjuncture is delayed until sufficient pixels have been recursively filtered for the noise level after the disjuncture to have been reduced to approximately that before the disjuncture.

[0008]   In a different aspect, the present invention consists in a video noise reduction filter comprising a temporal recursive filter; means for disabling recursion in the temporal recursive filter on detection of a disjuncture so that pixel information after the disjuncture is not recursively combined with pixel information prior to the disjuncture; a delay path affording multiple filter outputs mutually delayed by picture intervals; and means for selecting between said filter outputs on detection of a disjuncture so that recursively filtered pixel information prior to a disjuncture continues to provide the noise reduced output, until pixel information after the disjuncture has been recursively filtered to an appropriate degree of noise reduction.

[0009]   The present invention recognises that, taking the example of a shot change, the visually disturbing effect of replacing a quiet, heavily noise-reduced shot by the first noisy field of a new shot can be avoided by delaying showing the new shot until sufficient fields have been recursively filtered for the noise level on the new shot to have approached or equalled that of the current shot. The same approach applies of course pixel-by-pixel in the face of motion.

[0010]   The present invention will now be described by way of examples with reference to the accompanying drawings in which:-

Figure 1 is a block diagram of a well known temporal recursive noise reduction filter;

Figure 2 is a diagram illustrating the problem which is addressed by the present invention; and

Figure 3 is a diagram of a noise reducer according to one embodiment of this invention.

[0011]   It is convenient to describe first a temporal noise reduction filter according to the prior art. Referring to Figure 1, a subtractor 10 serves to derive the difference between the input video signal at terminal 12 and the signal at the output 14 of the filter, delayed by one frame in delay 16. The frame difference signal which is output by the subtractor 10 passes through a multiplier 18, the coefficient **k** of which is generated in noise measurement system and control block 20 which receives the frame difference signal as an input. In this arrangement, the rectified and filtered difference between the incoming signal and the frame delayed output of the filter is taken as a measure of motion. The signal

passing through multiplier 18 is added in adder 22 to the output of frame delay 16 to derive the filter output on terminal 14.

[0012] It will be recognised that the circuit of Figure 1 serves, for each pixel, to add to the filter output in the previous frame, **k** times the difference between the current pixel and the filter output in the previous frame. In the absence of motion, that is to say with a small frame difference signal outputted from subtractor 10, a value is chosen for **k** of perhaps 0.5. The filter output in that example will comprise 50% of the current frame, 25% of the preceding frame, 12.5% of the next preceding frame and so on. If motion is detected, that is to say the frame difference signal output from subtractor 10 exceeds a predetermined threshold, the value of **k** is set to unity. The combined effect of subtractor 10 and adder 22 is then first to subtract and then to add the filter output from the preceding frame leaving only information from the current frame. Setting the value of **k** to unity accordingly disables the recursion.

[0013] Turning now to Figure 2, an object 50 is depicted as moving in position between frame i and frame i+1. A motion signal **k** is illustrated, being the rectified difference between frame i and frame i+1. It will be seen that the value of **k** goes high at the leading edge of the object in frame i and falls at the leading edge of the object in frame i+1. Similarly, the value of **k** goes high at the trailing edge of the object in frame i and falls at the trailing edge of the object in frame i+1. It will be understood that during the intervals over which the value of **k** is high, the recursive noise reduction is disabled. There are thus created regions in the picture at the edges of the moving object at which there is no noise reduction. These regions are shown for frame i+1 at **a** and **b**.

[0014] Whist the motion signal **k** has been depicted as simply the rectified frame difference, it has been customary to filter the motion signal, causing spatial spreading.

[0015] The relatively more noisy regions **a** and **b** in the noise reduced output of the prior art filter represent an artifact, the visual effect of which becomes more disturbing as the noise reduction and other qualities of the output image improve.

[0016] It is instructive to consider the noise level in a recursive noise reduction filter and how this affects the choice of an optimum value of **k**. It has been explained that where motion is detected, **k** should be unity to allow the motion through without recursion. In stationary areas, **k** controls the ratio of input signal to stored signal. The optimum value depends upon the level of noise currently on the stored signal. This depends, in turn, upon the length of time since motion was last detected and thus the degree to which recursion has reduced noise.

[0017] If the noise power on the input is σ_i^2 and on the stored signal is σ_s^2 then the noise on the output will be:

$$\sigma_o^2 = \sigma_i^2 \cdot k^2 + \sigma_s^2 \cdot (1-k)^2$$

This is a minimum if:

$$k_{opt} = \frac{1}{\left(1 + \dfrac{\sigma_i^2}{\sigma_s^2}\right)}$$

In which case:

$$\sigma_o^2 = \frac{\sigma_i^2}{\left(1 + \dfrac{\sigma_i^2}{\sigma_s^2}\right)}$$

[0018] Just after motion stops at the current point, $\sigma_s^2 = \sigma_i^2$, so $k_{opt} = 1/2$ and $\sigma_o^2 = \sigma_i^2/2$. This becomes the new stored signal. So on the next frame $\sigma_s^2 = \sigma_i^2/2$; $k_{opt} = 1/3$ and $\sigma_o^2 = \sigma_i^2/3$. So on successive frames the noise power is reduced by 1/2, 1/3, 1/4, 1/5,... etc. provided that the value of k is 1/2, 1/3, 1/4, 1/5,...etc.

[0019] In preferred forms of this invention, the derivation of **k** embodies this approach.

[0020] If the value of a particular pixel in successive pictures is denoted

$$a : b : c : d : e : \ldots\ldots$$

successive outputs of a recursive filter might be:-

$$a : \frac{(a+b)}{2} : \frac{(a+b+c)}{3} : \frac{(a+b+c+d)}{4}$$

[0021] If a disjuncture occurs between pixel values **d** and **e**, caused by motion, for example, or a shot change, recursion will be disabled and the filter output will take the form:-

$$a : \frac{(a+b)}{2} : \frac{(a+b+c)}{3} : \frac{(a+b+c+d)}{4} : e : \frac{(e+f)}{2} : \frac{(e+f+g)}{3}$$

[0022] It will be understood that the noise level will increase significantly after:-

$$\frac{(a+b+c+d)}{4}$$

[0023] In an embodiment of this invention, the visual effect of increased noise in e is avoided by introducing a picture interval delay or delays and continuing to output:-

$$\frac{(a+b+c+d)}{4}$$

until the recursive filter has produced an output following the disjuncture, which is appropriately noise reduced, for example:-

$$\frac{(e+f+g+h)}{4}$$

[0024] An example of a noise reducer according to the invention will now be described with reference to Figure 3. It will be seen that the left-hand portion of the circuit, marked "recursive section", corresponds generally to the previously described temporal noise reduction filter. It will accordingly not be necessary to describe again the function of subtractor 210, multiplier 218, adder 222 and frame delay 216. In this embodiment, derivation of the signal **k** is performed in two stages. A motion detector block 250 receives the output from subtractor 210 and carries out appropriate filtering. A motion detection signal is then passed to one input of a motion control block 252, one function of this block being to provide a **k** signal having the properties discussed above, by which the correct proportions are maintained in the recursion to optimise noise reduction. To ensure that **k** follows this optimum sequence, the current value of:-

$$n_o = \frac{\sigma_i^2}{\sigma_o^2}$$

is stored for each pixel in the frame using a loop containing frame delay 254. The motion control block 252 additionally derives a signal **m**. The function of which will be described later.

[0025] The right-hand section of Figure 3 comprises a switched delay line giving up to three frames of delay. The frame delay 216 of the recursive section doubles as the first frame delay in a transversal section and there are additional frame delays 256 and 251. Switches 260, 262 and 269 are provided to select appropriate outputs from the frame delay path. Switch 260 selects between the output 214 of the recursive noise reduction filter and the point 266 of the output from the frame delay 216. The switch 262 selects between the output of the switch 260 and the point 268 intermediate between frame delays 256 and 251. Switch 269 switches between the output of switch 262 and the point 270 at the output of frame delay 251.

[0026] The control input of switch 260 is the signal **m** from the motion control block 252. This signal passes through frame delays 272 and 274 to provide the control inputs for switches 262 and 269 respectively.

[0027] The frame delays 216, 256 and 251 may be regarded as a picture-interval delay path affording, through the switches 260, 262 and 269 picture delayed outputs from the recursive filter. By suitable control of the signal **m**, it is arranged that each of the switches selects between the quietest of its two inputs.

[0028] The switch 260 can choose between the output of the recursive section and its stored output. From the previous analysis, the noise power on the output is:-

$$\sigma_o^2 = \sigma_i^2 \cdot k^2 + \sigma_s^2 \cdot (1 - k)^2$$

So **m** should select the stored output if:-

$$\sigma_s^2 < \sigma_i^2 \cdot k^2 + \sigma_s^2 \cdot (1 - k)^2$$

This condition reduces to:-

$$k > \frac{2}{1 + \dfrac{\sigma_i^2}{\sigma_s^2}}$$

[0029]   In practice the value of **k** (generated by analysis of the motion) will pass very rapidly between k_{opt} and unity. So the exact threshold is not critical.

[0030]   The next switch can choose between the previous delayed output, and the output of the first switch. If the first switch is currently selecting the stored output, then the second switch is offered delayed versions of the signals offered to the first switch, and so it can use a delayed version of the same decision (**m**). On the other hand, if the first is currently selecting the nondelayed output (because it is quieter than the delayed output) then the second switch should ideally remake the decision using a lower threshold. However, since the threshold is not really critical, satisfactory results are obtained by simply using the original decision (**m**) delayed by one frame in both cases. Similarly, subsequent switches can also be controlled by delayed versions of **m**. The slight error introduced by this simplification can be reduced on average by using a slightly lower threshold to generate **m**.

[0031]   The motion control block can be implemented in many ways. The simplest is probably a PROM containing pre-computed output values for all combinations of its inputs.

[0032]   To clarify the operation of the circuit, the previous notation will be employed of successive pixel values **a**, **b**, **c**, **d**... separated by a picture interval, with a disjuncture such as a shot change occurring between **d** and **e**. The signal appearing at critical locations are shown in the following table:-

	214	266	268	270	m	260	262	out
a	a	z	y	x	1	z	?	?
b	$\frac{a+b}{2}$	a	z	y	0	$\frac{a+b}{2}$	z	?
c	$\frac{a+b+c}{3}$	$\frac{a+b}{2}$	a	z	0	$\frac{a+b+c}{3}$	$\frac{a+b+c}{3}$	z
d	$\frac{a+b+c+d}{4}$		$\frac{a+b}{2}$	a	0	$\frac{a+b+c+d}{4}$	$\frac{a+b+c+d}{4}$	$\frac{a+b+c+d}{4}$
e	e	$\frac{a+b+c+d}{4}$	$\frac{a+b+c}{3}$	$\frac{a+b}{2}$	1	$\frac{a+b+c+d}{4}$	$\frac{a+b+c+d}{4}$	$\frac{a+b+c+d}{4}$
f	$\frac{e+f}{2}$	e	$\frac{a+b+c+d}{4}$	$\frac{a+b+c}{3}$	0	$\frac{e+f}{2}$	$\frac{a+b+c+d}{4}$	$\frac{a+b+c+d}{4}$
g	$\frac{e+f+g}{3}$	$\frac{e+f}{2}$	e	$\frac{a+b+c+d}{4}$	0	$\frac{e+f+g}{3}$	$\frac{e+f+g}{3}$	$\frac{a+b+c+d}{4}$
h	$\frac{e+f+g+h}{4}$	$\frac{e+f+g}{3}$	$\frac{e+f}{2}$	e	0	$\frac{e+f+g+h}{4}$	$\frac{e+f+g+h}{4}$	$\frac{e+f+g+h}{4}$
j	$\frac{e+f+g+h+i}{5}$	$\frac{e+f+g+h}{4}$	$\frac{e+f+g}{3}$	$\frac{e+f}{2}$	0	$\frac{e+f+g+h+i}{5}$	$\frac{e+f+g+h+i}{5}$	$\frac{e+f+g+h+i}{5}$

[0033]   It will be seen that when the value **e** appears at the input of the filter, the previously noise reduced value:-

$$\frac{a+b+c+d}{4}$$

is continued to be output until a further three values **f**, **g**, **h** have been received at the input enabling recursive noise reduction following the disjuncture to create a value which has the same noise value:-

$$\frac{e+f+g+h}{4}$$

[0034] It should be understood that the described arrangement of delays and switches is but one example of how choices can be made between delayed outputs of the recursive filter to select outputs having minimum noise. More generally, this invention has been described by way of examples only and a wide variety of possible modifications are possible without departing from the scope of the invention.

Claims

1. A method of noise reduction in a video signal, in which pixel information is recursively filtered to produce a noise reduced output, with recursion being disabled at a disjuncture so that pixel information after the disjuncture is not recursively combined with pixel information prior to the disjuncture, wherein, after the disjuncture, recursively filtered pixel information prior to a disjuncture continues to provide the noise reduced output, until pixel information after the disjuncture has been recursively filtered to an appropriate degree of noise reduction.

2. A method according to Claim 1, wherein the output of a recursive filter is presented to a picture interval delay chain and, following detection of a disjuncture and disabling of recursion, a selection is made between picture interval delayed filter outputs.

3. A method according to Claim 1 or Claim 2, wherein on detection of a disjuncture in the form of a shot change, from a first shot to a second shot, outputting of fields from the second shot is delayed until sufficient fields have been recursively filtered for the noise level on the second shot to have been reduced to approximately that of the first.

4. A method according to Claim 1 or Claim 2, wherein on detection of a disjuncture in the form of motion, outputting of pixels arising after the disjuncture is delayed until sufficient pixels have been recursively filtered for the noise level after the disjuncture to have been reduced to approximately that before the disjuncture.

5. A method according to any one of the preceding claims, wherein the recursion is controlled after a disjuncture such that available pixels contribute equally to the filter output.

6. A method according to Claim 5, in which the recursion constant is varied in dependence upon the count of picture intervals since a disjuncture leading to disabling of recursion.

7. A method according to any one of Claims 1 to 4, wherein the recursion constant is varied after a disjuncture in dependence upon the count of picture intervals since the disjuncture, to minimise the output noise level.

8. A video noise reduction filter comprising a temporal recursive filter; means for disabling recursion in the temporal recursive filter on detection of a disjuncture so that pixel information after the disjuncture is not recursively combined with pixel information prior to the disjuncture; a delay path affording multiple filter outputs mutually delayed by picture intervals; and means for selecting between said filter outputs on detection of a disjuncture so that recursively filtered pixel information prior to a disjuncture continues to provide the noise reduced output, until pixel information after the disjuncture has been recursively filtered to an appropriate degree of noise reduction.

9. A video noise reduction filter according to Claim 8, wherein the means for selecting between multiple filter outputs serves to select the output having the minimum noise level.

Patentansprüche

1. Verfahren zur Rausch- bzw. Störungsverminderung in einem Videosignal, bei dem Pixel-Informationen rekursiv bzw. wiederholbar gefiltert werden, um einen störungs- bzw. rauschreduzierten Ausgang zu erzeugen, wobei die Rekursion bei einer Unterbrechung gesperrt wird, so dass Pixel- bzw. Bildelementinformationen nach der Unterbrechung nicht rekursiv bzw. wiederholbar mit Pixel- bzw. Bildinformationen vor der Unterbrechung kombiniert werden, wobei nach der Unterbrechung rekursiv gefilterte Pixel- bzw. Bildelementinformationen vor einer Unterbrechung fortfahren, den rausch- bzw. störungsreduzierten Ausgang zur Verfügung zu stellen, bis Pixel- bzw. Bildinformationen nach der Unterbrechung rekursiv bis zu einem passenden bzw. geeigneten Grad der Rausch- bzw. Störungsverringerung gefiltert worden sind.

2. Verfahren nach Anspruch 1, wobei der Ausgang eines rekursiven Filters an eine Bildintervallverzögerungskette

angelegt wird und der Erfassung einer Unterbrechung unter Sperrung der Rekursion folgend eine Auswahl zwischen bildintervallverzögerten Filterausgängen durchgeführt wird.

3. Verfahren nach einem der Ansprüche 1 oder 2, wobei bei der Erfassung einer Unterbrechung in der Form eines Bildwechsels von einem ersten Bild zu einem zweiten Bild die Ausgabe von Feldern von dem zweiten Bild verzögert wird, bis ausreichend Felder rekursiv gefiltert worden sind, um den Störungs- bzw. Rauschpegel auf dem zweiten Bild rekursiv näherungsweise auf den des ersten reduziert zu haben.

4. Verfahren nach einem der Ansprüche 1 oder 2, wobei bei der Erfassung einer Unterbrechung in der Form einer Bewegung die Ausgabe von Pixeln bzw. Bildelementen, die nach der Unterbrechung erscheinen, verzögert wird, bis ausreichend Pixel bzw. Bildelemente rekursiv gefiltert worden sind, um den Störungs- bzw. Rauschpegel nach der Unterbrechung auf näherungsweise den vor der Unterbrechung reduziert zu haben.

5. Verfahren nach einem der vorangehenden Ansprüche, wobei die Rekursion so nach einer Unterbrechung gesteuert wird, dass verfügbare Pixel bzw. Bildelemente gleichermassen zu dem Filterausgang beitragen.

6. Verfahren nach Anspruch 5, in dem die Rekursionskonstante in Abhängigkeit von der Zahl der Bildintervalle seit einer Unterbrechung verändert wird, was zu einer Sperrung der Rekursion führt.

7. Verfahren nach einem der Ansprüche 1 bis 4, wobei die Rekursionskonstante nach einer Unterbrechung in Abhängigkeit von der Zahl der Bildintervalle seit der Unterbrechung verändert wird, um den Ausgangsrausch- bzw. -Störungspegel zu minimieren.

8. Videorausch bzw. -Störungsverringerungsfilter, der aufweist, einen temporären Rekursionsfilter; Mittel zum Sperren der Rekursion in dem temporären Rekursionsfilter bei Erfassung einer Unterbrechung, so dass Pixel- bzw. Bildelementinformationen nach der Unterbrechung nicht mit Pixel- bzw. Bildelementinformationen vor der Unterbrechung rekursiv kombiniert werden; einen Verzögerungspfad, der mehrere Filterausgänge aufbringt, die gegenseitig um Bildintervalle verzögert sind; und Mittel, um zwischen den Filterausgängen bei Erfassung einer Unterbrechung auszuwählen, so dass rekursiv gefilterte Pixel- bzw. Bildelementinformationen vor einer Unterbrechung fortfahren, einen störungs- bzw. rauschverringerten Ausgang zur Verfügung zu stellen, bis Bildelementinformationen nach der Unterbrechung rekursiv bis zu einem passenden bzw. angemessenen Grad der Störungs- bzw. Rauschverringerung gefiltert worden sind.

9. Videorausch- bzw. Störungsverringerungsfilter gemäß Anspruch 8, wobei die Mittel zum Auswählen zwischen mehreren Filterausgängen dazu dienen, den Ausgang auszuwählen, der den minimalen Störungs- bzw. Rauschpegel hat.

Revendications

1. Procédé de réduction de bruit dans un signal vidéo, dans lequel des informations de pixel sont filtrées récursivement pour produire une sortie à bruit réduit, la récursion étant invalidée à la disjonction pour que des informations de pixel après la disjonction ne soient pas récursivement combinées avec des informations de pixel avant la disjonction, où, après la disjonction, des informations de pixel filtrées récursivement avant une disjonction continuent à fournir une sortie de bruit réduit, jusqu'à ce que les informations de pixel après la disjonction aient été filtrées récursivement à un degré de réduction de bruit approprié.

2. Procédé selon la revendication 1, dans lequel la sortie d'un filtre récursif est présentée à une chaîne de retard d'intervalle d'image et, après détection d'une disjonction et invalidation de la récursion, une sélection est effectuée entre des sorties de filtre retardées d'intervalle d'image.

3. Procédé selon la revendication 1 ou la revendication 2, dans lequel sur détection d'une disjonction sous la forme d'un changement de prise de vue, d'une première prise de vue à une seconde prise de vue, la fourniture des trames de la seconde prise de vue est retardée jusqu'à ce que des trames suffisantes aient été filtrées récursivement pour que le niveau de bruit de la seconde prise de vue ait été réduit approximativement à celui de la première.

4. Procédé selon la revendication 1 ou la revendication 2, où sur détection d'une disjonction sous la forme de mouvement, la fourniture des pixels se produisant après que la disjonction a été retardée jusqu'à ce que suffisamment

de pixels aient été filtrés récursivement pour que le niveau de bruit après la disjonction ait été réduit approximativement à celui avant la disjonction.

5. Procédé selon l'une quelconque des revendications précédentes, dans lequel la réduction est commandée après une disjonction pour que des pixels disponibles contribuent également à la sortie de filtre.

6. Procédé selon la revendication 5, dans lequel la constante de réduction varie en fonction du comptage des intervalles d'image depuis une disjonction conduisant à une invalidation de la récursion.

7. Procédé selon l'une quelconque des revendications 1 à 4, dans lequel la constante de réduction varie après une disjonction en fonction du comptage des intervalles de pixels depuis la disjonction, pour minimiser le niveau de bruit de sortie.

8. Filtre de réduction de bruit vidéo comprenant un filtre récursif temporel ; un moyen pour invalider une récursion dans le filtre récursif temporel à la détection d'une disjonction pour que des informations de pixel après la disjonction ne soient pas récursivement combinées avec des informations de pixel avant la disjonction ; un chemin de retard offrant de multiples sorties de filtre mutuellement retardées par des intervalles d'image ; et un moyen pour sélectionner entre lesdites sorties de filtre lors de la détection d'une disjonction de sorte que des informations de pixel filtrées récursivement avant une disjonction continuent à fournir la sortie réduite de bruit, jusqu'à ce que les informations de pixel après la disjonction aient été récursivement filtrées à un degré de réduction de bruit approprié.

9. Filtre de réduction de bruit vidéo selon la revendication 8, dans lequel le moyen pour sélectionner entre des multiples sorties de filtre sert à sélectionner la sortie ayant le niveau de bruit minimum.

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Fig.1.

Fig.2.
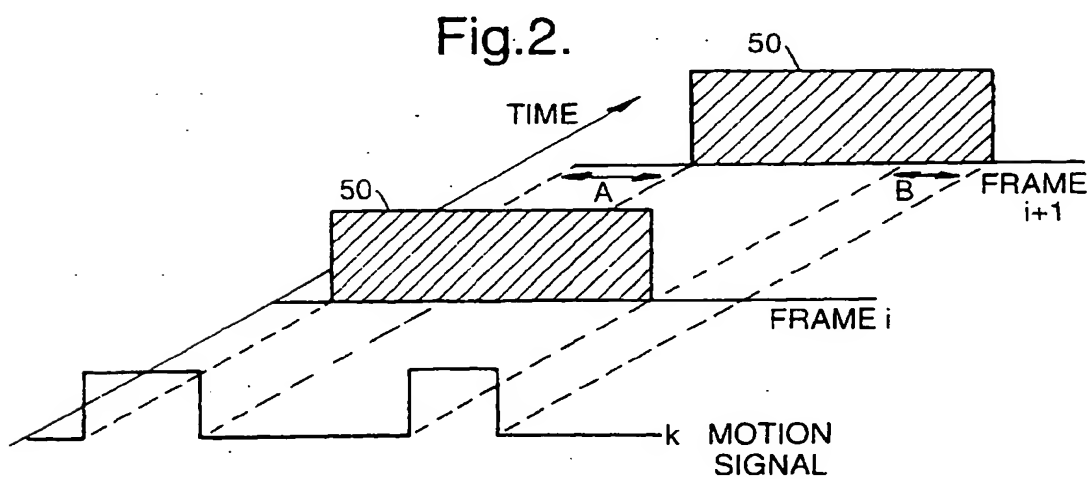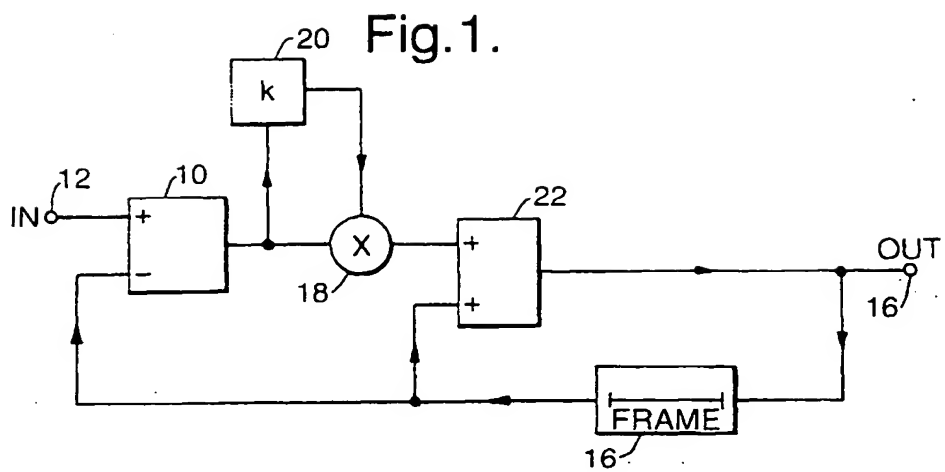
Fig.3.